

Acquired Morphological Changes of Mammalian Hair Scales¹

Zhang Wei (张伟) Yang Shuhui (杨淑慧)

College of Wildlife Resources, Northeast Forestry University, Harbin 150040, P. R. China

Wang Yingxu (王英旭)

The Second Biological Products Factory of Heilongjiang Province

Xu Yanchun (徐艳春)

Northeast Forestry University, Harbin 150040, P. R. China

Yuan Weibao (袁维葆)

Dalian Museum

Zhou Xiaowen (周晓雯)

Lanzhou Zoo

Abstract The original and postnatal scale patterns of guard hairs were compared. The comparisons illustrate that acquired morphological changes take place in the scales on the coarse section of guard hairs. Scales on this part changes from regular smooth to irregular wave. The primary reason would be friction. Scales on the lower part of guard hairs are thick and strong to bear friction. Additionally, they are berried in the bottom layer of pelage where friction is avoided. Scales on the coarse section are thin, broad, dense and overlap, and exposed in the environment as a cover of pelage. So friction always happen on them. Factors which enhance coefficient of friction and weaken keratin bonds are combined to damage hair scales. The results suggest that regular smooth and irregular wave are actually the same type exhibiting the same origin morphological characters, so they should be counted together in the species identification.

Key Words: Hair scale, Scale damage, Species identification, Acquired morphological change

Introduction

In the past 100 years, many studies indicated that morphological characters of mammalian hair scales can be an evidence to identify species^[1-7, 16-29]. Many types scale patterns have been defined, such as regular smooth, flattened, simple, dentate, serrate, crenate, elongate, acuminate, and ovate etc.^[1, 2, 5, 33]. Some certain scale patterns appear on the hair shaft by a certain sequence to illustrate the very species. A parameter, the ratio of each scale pattern to the total hair length, was adopted in species identification by some scientists^[2]. And, in forensic analysis, average distance between scale margins was used to identify individual. However, people found that it was too difficult to judge the critical lines between different scale patterns. On the tope part of hair shaft, the critical line varies so greatly that even data from hairs sampled from the same individual show a too large standard error to get a steady parameter. In the past few years, we have found that if we sum up the length of regular wave and smooth, we can get steady data, and there is a linear relationship between irregular wave and smooth. Our discovery illustrates that ir-

regular wave and smooth might from a certain original pattern, and changes happen in the original pattern in the postnatal environment. For more evidences to our idea, we conducted a series of studies.

Materials and Methods

Sampling

Both skin and hair samples are included in the materials. In November, 1997, minks(*Mustela vison*) and Nutria(*Myocaster coypus*) were selected in Harbin Zoo and Hengdaohezi Wildlife Breeding Farm when summer coat have been shielded and winter coat was developing. On each skin samples, hairs being in different developing period can be found. 10 skin samples were cut on each body immediately after the animal was killed with motor waste gas. Skin samples were fixed in the glutaric dialdehyde immediately after being sampled. We also cut 20 skin samples from each individual when the pelts were dry. Guard hairs were sampled directly from the living animals and specimen in the Fur Specimen Museum of the Northeast Forestry University. During sampling, skin and hair were protected from being contaminated,

¹ This projects is supported by Heilongjiang Natural Science Fund, 1996

damaged and deformed.

Optical microscopic and scanning electron microscopic Preparations^[17, 27, 31]

1. A few very short guard hairs were rubbed with coarse paper, damage degree being handled. The rubbing experiments were handled to be similar to the true environment facts as much as possible.

2. All hair samples were degreased in 1:1 solution of 95% alcohol and ether for 10 min, and washed 2 times in 100% alcohol for totally 5 min. Cleaned hairs were dried on clean filter paper.

3. Skin samples were cut parallel to the follicles to make some longitude sections of guard hair follicles before they were dehydrated in alcohol of deferent consistency, orderly 30%, 50%, 70%, 80%, 90%, 95%, 100%, 100% for 10 min in each consistency. Skin samples were dried in CO₂ critical point drier before they were ready for next step.

4. Cleaned and dehydrated hair and skin samples were fixed on the objective tables of scanning electron microscope (SEM) on which a thin gold membrane was sprayed in IB-5 ion sputter.

5. Gold covered samples were observed and pictures were taken under HITACHI-520 SEM.

6. Cleaned hair samples were put on a clean 1.5-2.0 mm thickness organic glass slide. On and beneath the organic glass slide, 2 inorganic glass slides were fixed. 3 slides were trapped together tightly and put bake oven for 2 h with adjusted temperature of

110-120°C.

7. Took out the slides and removed the trappers inorganic glass slides and hair samples after they were cooled. Organic glass slides with hair scale impressions could be observed and measured under optical microscope.

Results

Along perfect and fully grown hair shafts, we found that scale patterns are organized from root to tip sequentially. They are regular smooth, wide valve, ovate, elongate, acuminate valve, ovate, regular smooth, irregular wave, serrate and crown. Regular wave always appears at the very root end and the upper part of hair shaft. Irregular wave is only seen at the upper part next to regular smooth. There are various types of transitional valves between two adjacent patterns.

Short guard hairs sampled have not been fully grown. They are still in bottom layer of pelage. Due to their different developing stages, different part of the hair shaft can be found in the longitude sections of follicles. On the hairs whose coarse section have just grown out of the follicle, no irregular wave but regular smooth were found on the coarse section. On the hairs whose coarse section are still in the follicles, the same scale pattern was found. (See Fig.1).

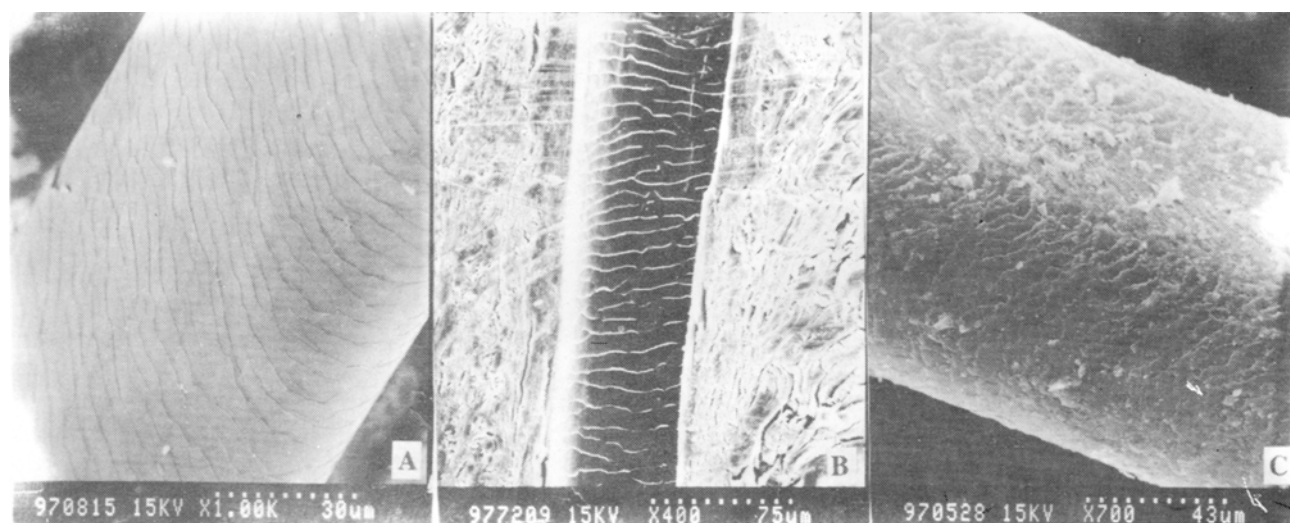


Fig. 1 Morphological characters of scale margins
smooth on coarse section of guard hairs (A) and follicular inner surface(B),
but irregular on the coarse section of matured guard hairs

In the longitude section of follicles, inner surface of inner root sheath shows no irregular scale margins. All morphological characters of follicular inner surface are corresponding to that of hair shafts. We can see regular smooth, elongate/acuminate valve,

ovate valve, broad valve, irregular smooth(Transitional type from valves to regular smooth), regular smooth and crown orderly on both hair shafts and all except irregular wave in follicular inner surface. (See Fig. 2).

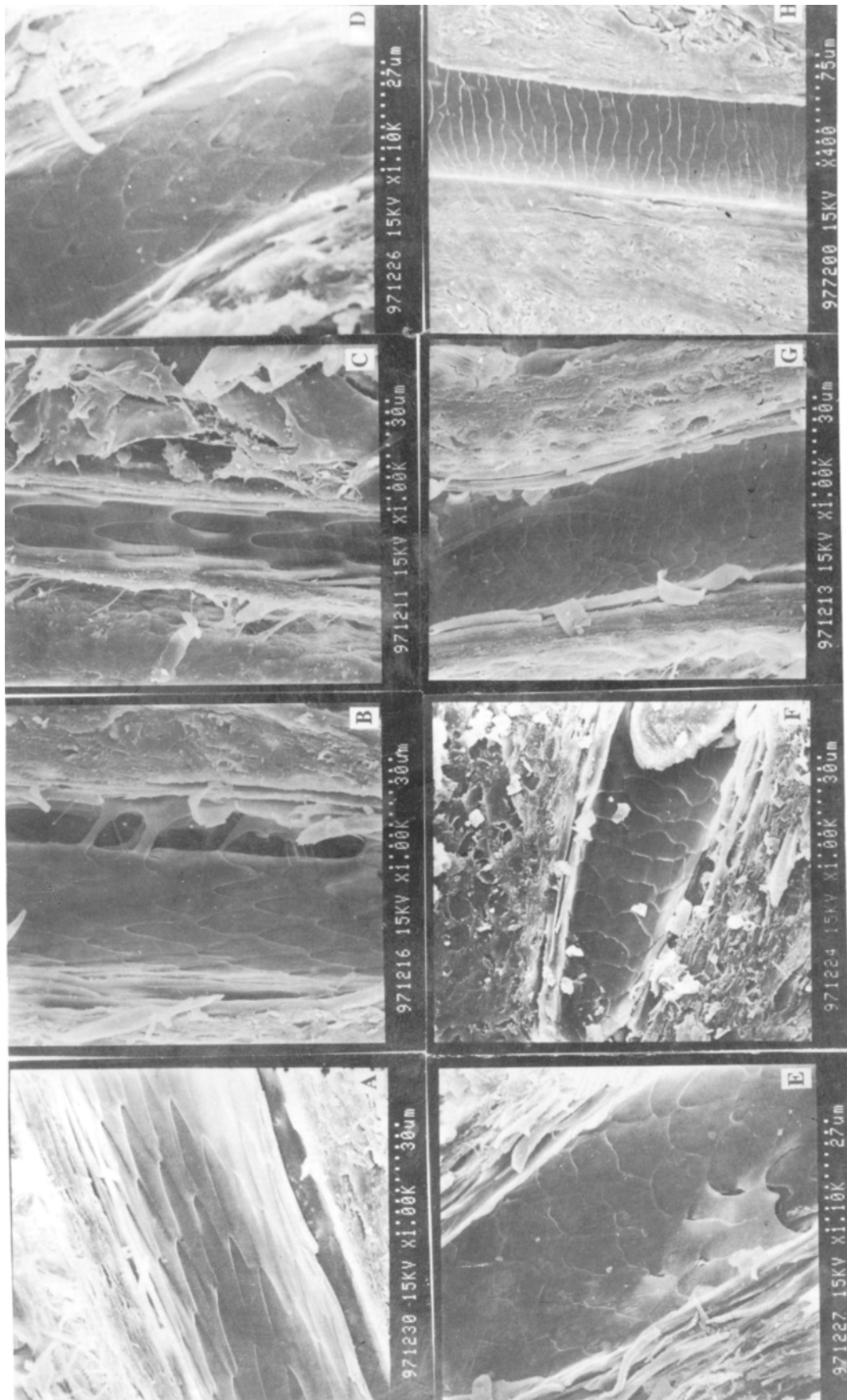


Fig. 2 Follicular inner surface corresponding to hair scales in morphology

A-B. acuminate valve; D. square valve; E. broad valve; F. transitional type II; G. transitional type II; H. regular smooth

The scale margins are smooth on the hair head part of short guard hairs. It becomes irregular after it

is rubbed. The heavier it is rubbed, the more irregular it will be. (See Fig. 3).

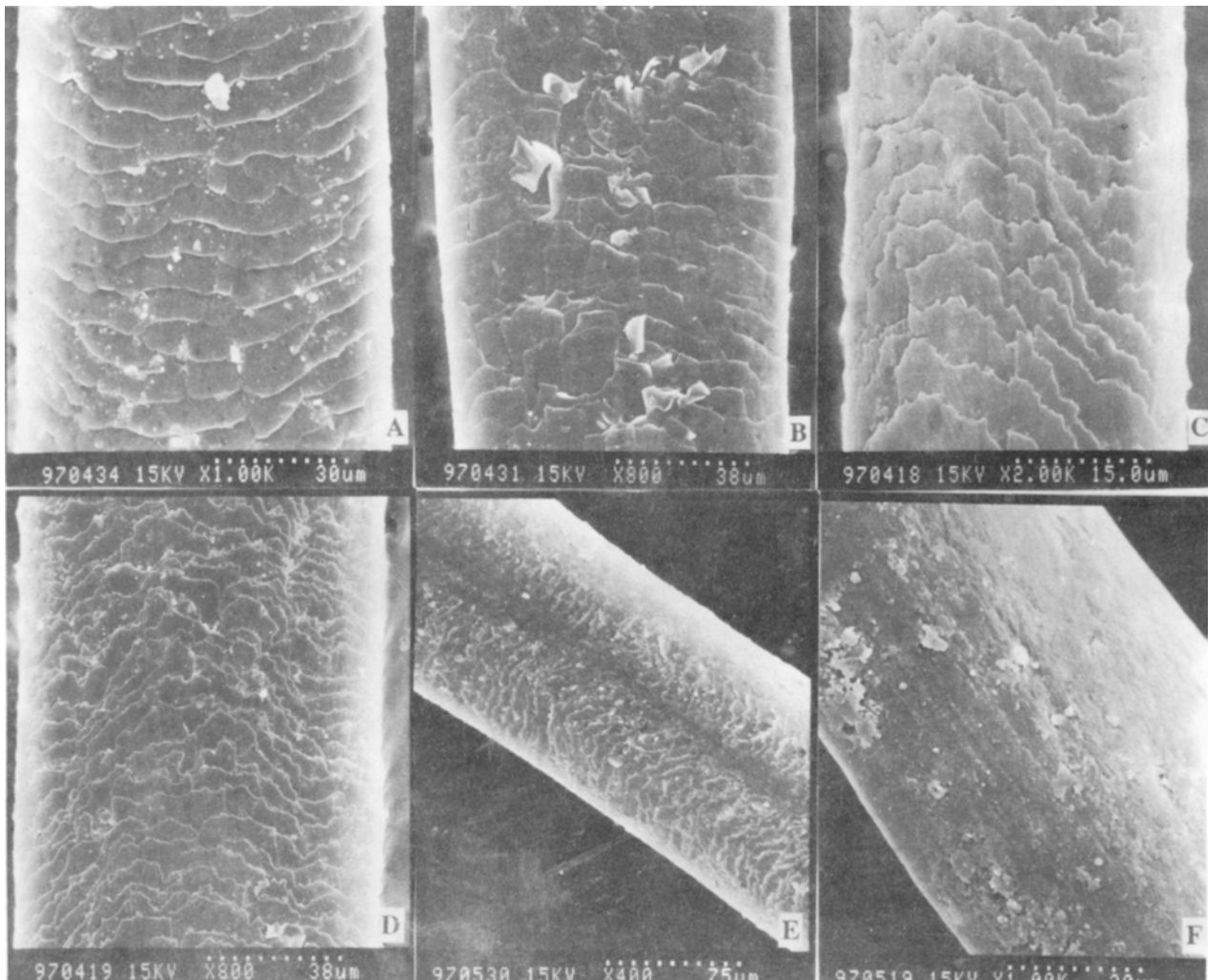


Fig. 3. Morphological changes when regular smooth is rubbed

A. regular smooth; B. slightly rubbed; C. heavily rubbed; D. slightly rubbed in nature;
E. heavier rubbing in nature; F. all scales rubbed off in nature

Discussion

It can be supposed to be true that morphological character of hair scales can be changed postnatally. The follicular inner surface is corresponding to the scales on hair shaft. Irregular scale margin can neither be found on hair head sections of short guard hairs nor on the follicular inner surface, but on the coarse section of matured guard hairs. This result seems to illustrate that some postnatal factors do make the scales change their original morphological characters.

Based on the rubbing experiments, one of the

postnatal factors are supposed to be environmental friction. Mammalian pelage consists of several layers, the over hair layer (may not exist in some species), guard hair layer and bottom layer. (See Fig. 4). The bottom layer is mainly made up of very weak and soft under hairs. Only elongate valve exists on the under hair shaft. Because of this type of scales and the weakness of under hair, the bottom layer is made very sticky. Shafts of guard hairs are strong enough to support the bottom layer to bear out pressure. At the same time, the bottom layer becomes steady. Very little relative movements of hair shafts happens in the layer. So it can be imagine that little move-

ments bring little friction although the scale pattern does have a high coefficient of friction. Naturally the structure of the bottom layer is protective to all kinds of scales. The guard hair layer consists of coarse section of guard hairs. This layer is the cover of the bottom layer and must be protective. The protective function is partly due to the coarse cortex, but mostly comes from the scales on the hair surface. As the cover of pelage, it must reduce friction when relative movement happens. Forces on the hair could be very strong. The most effective countermeasure should be

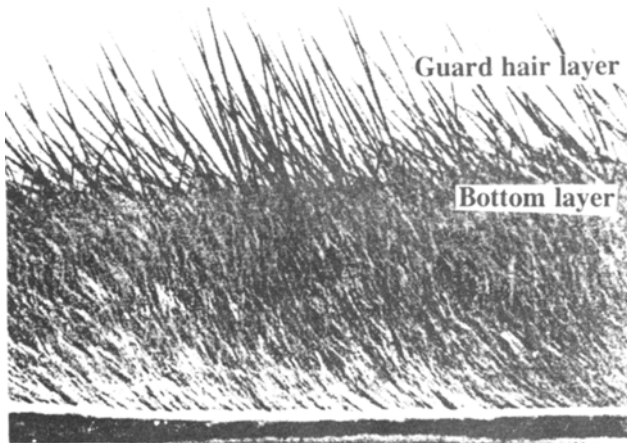


Fig. 4. Typical structure of mammalian pelage reducing the coefficient of friction. Regular smooth

type is characterized thin, wide, dense and overlap, so that the surface of hair can be very smooth. Macroscopically, we can see the guard hairs are shining under the sun. This is because of the dense scale margins are close enough to enhance the reflection of light. This structure of hair surface is very effective to reduce the coefficient of friction. However, scales are too thin to bear a very weak friction, so damage often happens.

Scale cells do not consist of typical α -keratin, instead, the cell matrix is full of Gly and Cys^[9-12]. Keratin molecules are bonded with disulfates. The mechanical character of matrix is isotropic. When friction happens, The cell will be broken in any direction rather than be tore open in longitude direction. When the animal is moving, guard hairs are flex enough to change their direction and position to reduce the friction. (See Fig. 5). In this case, the direction of friction always parallel to the axial direction of hair. The friction is reduced as much as possible, so does the damages. On the hairs we rubbed by hand show larger debris because of the different rubbing direction and the larger friction. The debris are dropped off from the scales in various shapes. In the natural environment, the friction are smaller, and the debris removed from the scales seem to be smaller. That is why the margins of irregular wave scales on matured guard hairs exhibit tiny dentate.

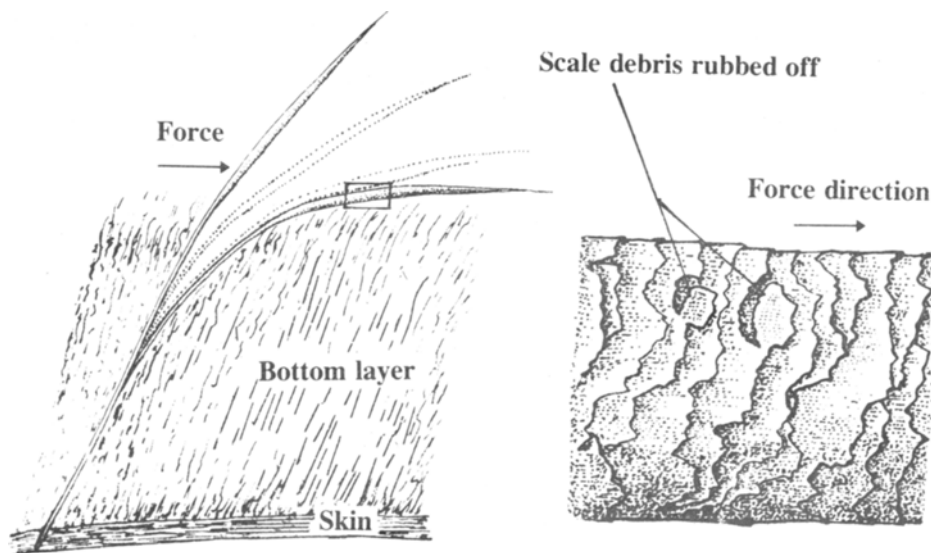


Fig. 5. Countermeasures of guard hair reducing friction

It was reported that many factors affect the friction and scale damage. pH is regarded the first important factor. pH may change the bonds in keratin molecules of hair scales. Too high and too low pH weakens the bonds stability, and the keratin becomes so easy to be damaged^[13]. High humidity provides more

chances that hydra molecules are bonded to keratin molecules, so bond energy holding the secondary structure of keratin polypeptides would be weakened. When too much H and O in keratin amino acids are bonded to hydra molecules, the polypeptide chains becomes very weak. A small friction may break them^[31]. Ultra violet radiation is harmful for scales. It

was reported that mink guard hairs are damaged seriously by UV in Qinghai High Plateau. The shape of scales changed greatly by UV^[15].

Generally, postnatal factors can change the original features of hair scales. The thin dense and overlap smooth and irregular wave patterns are very easily damaged by friction. Smooth and irregular wave are protective because of the special structure and the function reducing the friction. Other types of scales(valves) are too thick and strong to be damaged by friction, so the only acquired change happens on coarse section of guard hairs where smooth scales are. Since regular smooth and irregular wave have the same origin, they should be counted together as a same scale type in species identification.

References

1. 景松岩等. 1992. 中国熊类被毛的形态结构及化学组成的比较研究. 第二届东亚熊类会议论文集(马建章主编), 东北林业大学出版社, 206-217
2. 景松岩等. 1993. 毛皮学. 哈尔滨: 东北林业大学出版社, 19-52; 66-73; 103-114; 200-214
3. 朱小曼等. 1987. 54种动物毛的扫描电子显微镜观察, 中国法医学杂志, (2):1
4. 王泽长. 1965. 哺乳动物被毛的比较形态. 中国动物学会三十周年学术讨论会论文摘要汇编
5. 金煜等. 1995. 中国猫科动物毛的结构与属间划分. 野生动物, (4): 29-30
6. 张伟等. 1994. 水獭针毛形态结构的稳定性与变异性的系统研究. 野生动物, (2): 35-38
7. 张伟等. 1994. 鱼鳞毛的鳞片类型与哺乳动物识别的关系. 东北林业大学学报, 22(3):121-123
8. 陈华豪等. 1988. 林业应用数理统计. 大连: 大连海运出版社, 185-241
9. Swift, J. A. 1979. Minimum depth electron probe X-ray micro-analysis as a means for determining the sulfur content of the human hair surface. Scanning, 2: 83-88.
10. Swift, J. A. et al. 1974. The chemistry of human hair cuticle, Part 1. A new method for the physical isolation of cuticle. J. Soc. Cosmet Chem., 25: 13-22
11. Swift, J. A. et al. 1974. The chemistry of human hair cuticle, Part 2. The isolation and amino acid analysis of the cell membranes and A-layer. J. Soc. Cosmet Chem., 25: 355-366
12. Swift, J. A. et al. 1976. The chemistry of human hair cuticle, Part 3. The isolation and amino acid analysis of various subfractions of the cuticle obtained by pronase and trypsin digestion. J. Soc. Cosmet Chem., 27: 289-300
13. Robinson, V. N. E. 1976. A study of damaged hair. J. Soc. Cosmet Chem., 27: 155-161.
14. Wolfram, L. J. et al. 1971. Some observations on the hair cuticle. J. Soc. Cosmet Chem., 22: 839-850.
15. Kondo, K. et al. 1988. Morphological and chemical studies on the bending guard hairs of mink(*Mustela vison*) ranches in Qinghai Plateau, China. Scientifur, 12(1):13-16.
16. Day, M. G. 1966. Identification of hair and feather remains in the gut and faeces of stoats and weasels. Journal of Zoology, 148: 201-217
17. Williamson, V. H. H. 1951. Determination of hairs by impressions. Journal of Mammalogy, 32: 80-84.
18. Wildman, A. B. 1961. The identification of animal fibers. J. Forens. Sci., 1:1-8
19. Benedict, F. A. 1957. Hair structure as a genetic character in bats. Univ. Calif. Pul. Zool., 59: 285-548.
20. Mayer, W. V. 1952. The hair of California mammals with keys to the dorsal guard hairs of California mammals. Am. Midland Nat. 38: 480-512.
21. Stain, H. J. 1958. Key to guard hairs of middle western fur bearers. Journal of Wildlife Management, 22(1): 95-97.
22. Appleyard, H. M. 1960. Guide to the identification of animal fibres, Wool Industry Research Association, Leeds, England, 1-188
23. Haitlinger, R. 1968. Comparative studies in the morphology of hair representatives of the genus Apodemus Kaup, 1829, found in Poland. Zoology of Poland, 18: 347-380
24. Dziurdzik, B. 1973. Key to the identification of hairs of mammals from Poland. Acta Zool. Cracov, 18: 73-91.
25. Dziurdzik, B. 1978. Histological structure of hair in the Gliridae(Rodentia). Acta Zool. Cracov, 23: 1-10.
26. Twigg, G. I. 1975. Finding mammals---their signs and remains. In: Techniques in Mammalogy. Mamm. Rev., 5: 77-78.
27. Short, H. L. 1978. Analysis of cuticular scales on hairs using the scanning electron microscope. Journal of Mammalogy, 59: 261-267
28. Teerink, B. J. 1991. Hair of west European mammals: atlas and identification key. Cambridge University Press, New York, 1-221.
29. Moore, T. D. et al., 1974. Identification of the dorsal guard hairs of some mammals of Wyoming. Wyoming Game and Fish Department, 1-177.
30. Kassenbeck, A. J. et al. 1985. Morphology and fine structure of hair, In: Hair research (Ed.) by Orfanos et al.. Springer-Verlag Berlin Heidelberg. 52-64.
31. Mahrle, G. et al. 1981. The use of scanning-electron microscopy to assess damage of hair. In: Hair Research (Ed. by C. E. Orfanos etc.), Springer-verlag Berlin Heidelberg, 524-528.
32. Breuer, M. M. 1981. The binding of small molecules and polymers to keratin and their effects on the physico-chemical and surface properties of hair fibres. In: Hair Research (Ed. by C. E. Orfanos etc.), Springer-verlag Berlin Heidelberg, 96-115.
33. Hausemann, L. A. 1920. Structural characteristics of the hair of mammals. American Naturalist, 54: 496-523.

(Responsible Editor: Chai Ruihai)